

## DESCRIPTION

## METHOD FOR CONTROLLING IMAGE-FORMING APPARATUS

## 5 TECHNICAL FIELD

The present invention relates to a method of controlling an optical deflection apparatus including an oscillator which can be formed using, for example, a technique related to a technical field of a micro-  
10 structure. In particular, the present invention relates to a method of controlling an image-forming apparatus using the optical deflection apparatus, such as a scanning display, a laser beam printer, or a digital copying machine.

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## BACKGROUND ART

Up to now, various optical deflection apparatuses in which a mirror is resonated have been proposed. As compared with a light-scanning optical  
20 system using a rotary polygonal mirror such as a polygon mirror, a resonance type optical deflection apparatus has the features that the size of the optical deflection apparatus can be significantly reduced; power consumption is small because a Q value  
25 is high; there is theoretically no optical face tangle error; an optical deflection apparatus made of single-crystalline Si manufactured by particularly a

semiconductor process theoretically has no metal fatigue and excellent durability (see Japanese Patent Application Laid-Open No. S57-008520).

However, a resonance type optical deflector has  
5 a problem in which a material characteristic changes with a variation in ambient temperature to shift a resonance frequency, thereby dramatically reducing a deflection angle. In order to solve the problem, there have been proposed many methods capable of  
10 changing a drive frequency in response to a shift of the resonance frequency, including a method capable of changing a drive frequency of an excitation current applied in response to the shift of the resonance frequency by detecting the deflection angle  
15 based on induced electromotive force (see Japanese Patent Application Laid-Open No. 2001-305471).

There have been also proposed many methods capable of changing the resonance frequency based on temperature compensation, including a method of  
20 controlling the resonance frequency of an optical deflector by using a heater, a temperature sensor, and a temperature control circuit, which are provided for the optical deflector (Japanese Patent Application Laid-Open No. H05-260267).

25 Here, the temperature of the optical deflector is varied not only by ambient temperature but also by laser light modulated according to image data when

laser light from a laser light source is deflected. As compared with the former variation by ambient temperature, the latter variation by the laser light is a very rapid change and its variation time can be  
5 estimated to be several tens of milliseconds or less. Here, in the case of a low-power laser light source, a variation in temperature thereof is negligibly small. However, when a high-power laser light source is used, a variation in temperature thereof is more  
10 significantly caused. In an image-forming apparatus using such an optical deflector, the resonance frequency of the optical deflector changes with a variation in temperature thereof, so that a projected image deteriorates.

15       A time required to stabilize a variation in oscillation state of the optical deflector is proportional to a  $Q$  value. Therefore, when the resonance type optical deflector has a high  $Q$  value, a stabilization time can be estimated to be several  
20 tens of milliseconds. Even when the temperature of the optical deflector is changed by a heater or the like, a stabilization time can be estimated to be several tens of milliseconds. As described above, a variation in temperature of the optical deflector due  
25 to the modulation of deflected light is caused on the same order as an oscillation stabilization time of the optical deflector. Thus, it is difficult to

control the variation in temperature of the optical deflector due to the modulation of the deflected light using the above-mentioned conventional techniques.

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#### DISCLOSURE OF INVENTION

In view of the above-mentioned problems, the present invention provides a method of controlling an image-forming apparatus including an optical deflection apparatus having an optical deflector in which an oscillator is supported by an elastic support portion to be oscillatable about a support substrate, temperature control means for controlling a temperature of the optical deflector, at least one light source, and modulation means for modulating the light source, wherein light from the light source is deflected by the optical deflector, and at least a part of the light is irradiated on an object to be irradiated to form an image, the method including controlling the temperature of the optical deflector by the temperature control means based on a modulation signal from the modulation means so as to stabilize a resonance frequency of the optical deflector.

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In the above-mentioned method of the present invention, the temperature control means is preferably the light source which emits light other

than drawing light for forming an image so as to stabilize a resonance frequency of the optical deflector, and a total amount of the light emitted from a light source to the optical deflector is preferably controlled such that the total amount becomes close to a predetermined amount within the arbitrary unit time.

In the above-mentioned method of the present invention, the temperature control means preferably include a heating element mounted on a part of the optical deflector adjusting a temperature of an optical deflector, and the temperature of the optical deflector is preferably controlled by the heating element so as to stabilize a resonance frequency of the optical deflector.

According to the present invention, even in an optical deflection apparatus using a light source such as a high-power laser light source, a variation in temperature of the optical deflector due to modulation of deflected light based on drawing data can be compensated by compensation light irradiation or compensation heating. Therefore, a preferable oscillating state can be maintained. Thus, a preferable image can be formed by an image-forming apparatus using the optical deflection apparatus according to the method of the present invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic structural diagram for explaining a method of controlling an image-forming apparatus according to a first embodiment of the present invention;

FIG. 2 is a graph showing an oscillation trail of an optical deflector in the image-forming apparatus;

FIG. 3 is an explanatory view showing a non-drawing region filter in the image-forming apparatus;

FIG. 4 is an explanatory view showing a unit compensation time;

FIG. 5 is a schematic structural diagram for explaining a method of controlling an image-forming apparatus according to a second embodiment of the present invention;

FIG. 6 is an explanatory view showing a temperature compensation laser filter in the image forming apparatus;

FIG. 7 is a schematic structural diagram for explaining a method of controlling an image-forming apparatus according to a third embodiment of the present invention;

FIG. 8 is a schematic structural diagram for explaining a method of controlling an image-forming apparatus according to a fourth embodiment of the present invention; and

FIG. 9 is a schematic structural diagram for explaining a method of controlling an image-forming apparatus according to a fifth embodiment of the present invention.

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#### BEST MODES FOR CARRYING OUT THE INVENTION

Hereinafter, in order to understand the present invention, specific embodiments will be described with reference to the accompanying drawings.

10 First, reference numerals in the drawings will be described below. Reference numeral 1 denotes an image-forming apparatus; 10, an optical deflector; 20, 21 and 22, light sources (laser light source, drawing laser light source, and temperature compensation  
15 laser light source); 30, a control unit; 41, a drawing region; 42, a drawing time; 43, a non-drawing time; 44, a specific time (unit compensation time); 51, 65 and 72, objects to be irradiated (a projection surface, a photosensitive member, and a screen); and  
20 60, a heating element.

#### (First Embodiment)

A first embodiment of the present invention will be described with reference to the drawings. FIG. 1 is a structural diagram for explaining a  
25 method of controlling an image-forming apparatus according to this embodiment. In this embodiment, the optical deflector 10 is composed of a movable

plate (or an oscillator), a support substrate, and an elastic support member for supporting the movable plate so as to be rotationally twistable about the support substrate. The optical deflector 10 deflects modulated light from the laser light source 20 serving as a semiconductor laser capable of performing direct modulation. The optical deflector 10 is driven and controlled by a drive control unit 31 of the control unit 30. The laser light source 20 is modulated and driven by a light source control unit 32 having modulation means, of the control unit 30. The light source control unit 32 has a function for converting drawing data obtained from an outside into a modulation signal and modulating and driving the laser light source 20 based on the modulation signal and has temperature control means for performing modulation and driving so as to stabilize a resonance frequency of the optical deflector 10.

The movable plate of the optical deflector 10 is driven for resonance, so that the driving becomes sinusoidal driving as shown in FIG. 2. In this embodiment, a region corresponding to 70% of the maximum amplitude of the movable plate is set as the drawing region 41. An image is formed on an object to be irradiated within the region by using deflection light caused by forward scanning and backward scanning of the optical deflector 10. Of

course, the image may be formed by only one of the two.

A scanning time for the drawing region 41 is the drawing time 42 and the rest is the non-drawing time 43. The drawing time 42 accounts for about 49.4% of a total time and the non-drawing time 43 accounts for about 50.6% thereof. In this embodiment, the region corresponding to 70% of the maximum amplitude of the movable plate is set as the drawing region 41. However, this percentage may be any percentage. In this embodiment, as shown in FIG. 3, the non-drawing region filter 52 is provided to prevent deflection light other than light for the drawing region 41, of light deflected by the optical deflector 10 from reaching the projection surface 51 corresponding to the object to be irradiated.

Further, in this embodiment, in order to correct a shifted resonance frequency of the optical deflector 10 which is caused due to a variation in irradiation amount of modulated light based on the drawing data, a half of an oscillation period including the drawing time 42 and the non-drawing time 43 as shown in FIG. 4 is set as the unit compensation time 44. Control is performed such that the total power of light emitted from the laser light source 20 to the optical deflector 10 within each of the plurality of unit compensation times 44 becomes a

predetermined power. More specifically, power of light which is emitted from the laser light source 20 within the drawing time 42 and absorbed by the optical deflector 10 is changed according to drawing data, so that the resonance frequency of the optical deflector 10 changes, thereby deteriorating an image. Therefore, the laser light source 20 emits light even within the non-drawing time 43. Thus, the total power of light with which the optical deflector 10 is irradiated within the unit compensation time 44 is constantly maintained to a predetermined power.

In other words, when the power of light with which the optical deflector 10 is irradiated within the drawing time 42 of the unit compensation time 44 is given by  $P_{ce}$  and the power of light with which the optical deflector 10 is irradiated within the non-drawing time 43 thereof is given by  $P_{ed}$ , power  $P_{to}$  of light with which the optical deflector 10 is irradiated within the unit compensation time 44 is expressed by  $P_{to} = P_{ce} + P_{ed}$  (Expression 1). The power  $P_{to}$  of light with which the optical deflector 10 is irradiated within the unit compensation time 44 is maintained to a predetermined power during an operating period of the image-forming apparatus. Therefore, the resonance frequency of the optical deflector 10 is stabilized regardless of drawing data, so preferable image formation can be realized.

The power  $P_{ce}$  of light with which the optical deflector 10 is irradiated within the drawing time 42 can be grasped in advance by the light source control unit 32. Therefore, the power of light to be emitted within the non-drawing time 43 following the drawing time 42 is determined by the above Expression 1 based on the power, and the irradiation of light having the determined power is executed. In this embodiment, such irradiation control is executed for each of the successive unit compensation times 44. The control may be executed for each of the discrete (for example, alternate) unit compensation times 44. The former control has an excellent effect for stabilizing the resonance frequency. Even in the latter control, there is an effect for stabilizing the resonance frequency.

In this embodiment, the unit compensation time 44 is set to the half of the oscillation period including the drawing time 42 and the non-drawing time 43. It may be set to any time which is an integral multiple of a  $1/4$  period (this is a minimum time which can include the drawing time 42 and the non-drawing time 43 at a predetermined rate in the case where a time is divided into the successive unit compensation times 44).

(Second Embodiment)

Next, a second embodiment of the present

invention will be described with reference to the drawings. FIG. 5 is a structural diagram for explaining a method of controlling an image-forming apparatus according to this embodiment. In FIG. 5, 5 the optical deflector 10, the drawing laser light source 21, and the drive control unit 31 of the control unit 30 correspond to those of the first embodiment.

In this embodiment, in order to correct a 10 shifted resonance frequency of the optical deflector 10 which is caused due to a variation in irradiation amount of modulated light based on the drawing data, the optical deflector is controlled such that the optical deflector 10 is irradiated with light from a 15 temperature compensation laser light source 22 which is different from the drawing laser light source 21 and the total power of the light with which the optical deflector 10 is irradiated constantly becomes a predetermined power within the unit compensation 20 time 44.

In other words, when power of light which is emitted from the drawing laser light source 21 within the unit compensation time 44 and absorbed by the optical deflector 10 is given by  $P_{dr}$ , and power of 25 light which is emitted from the temperature compensation laser light source 22 and absorbed by the optical deflector 10 is given by  $P_{co}$ , the power

Pto of light with which the optical deflector 10 is irradiated within the unit compensation time 44 is expressed by  $P_{to} = P_{dr} + P_{co}$  (Expression 2). Even in this embodiment, the power of light with which the optical deflector 10 is irradiated within the unit compensation time 44 is constantly maintained to a predetermined power during an operating period of the image-forming apparatus. Therefore, the resonance frequency of the optical deflector 10 is stabilized regardless of drawing data, so that preferable image formation can be realized.

In this embodiment, as shown in FIG. 6, in order to prevent light from the temperature compensation laser light source 22 from being projected onto the projection surface 51, a frequency of the drawing laser light source 21 is made different from that of the temperature compensation laser light source 22. A temperature compensation laser filter 53 for absorbing light from the temperature compensation laser light source 22 is inserted between the optical deflector 10 and the projection surface 51. Therefore, in this embodiment, a time for emitting light from the temperature compensation laser light source 22 is not limited to within the non-drawing time 43 and may be any time within the unit compensation time 44. For example, the unit compensation time 44 is set as a pixel.

scanning time. The drawing laser light source 21 and the temperature compensation laser light source 22 are alternately driven with reverse modulation modes (for example, when one source is turned on, the other source is turned off) within each pixel scanning time. Thus, the total power of the light with which the optical deflector 10 is irradiated within the pixel scanning time can be also maintained to a predetermined power. When the frequency of the drawing laser light source 21 is equal to that of the temperature compensation laser light source 22, it is necessary that the time for emitting light from the temperature compensation laser light source 22 be within the non-drawing time 43.

15 (Third Embodiment)

Next, a third embodiment of the present invention will be described with reference to the drawing. FIG. 7 is a structural diagram for explaining a method of controlling an image-forming apparatus according to this embodiment. In this embodiment, the optical deflector 10, the laser light source 20, and the drive control unit 31 of the control unit 30 correspond to those in the first embodiment. The light source control unit 32 has only a function for converting drawing data obtained from an outside into a modulation signal and then modulating and driving the laser light source 20

based on the modulation signal. A temperature control unit 33 of the control unit 30 controls a temperature of the optical deflector 10 based on the modulation signal by using a heating element (temperature control element) 60.

In this embodiment, the temperature control element 60 is located close to the optical deflector 10. More particularly, a heater is mounted on the elastic support member of the optical deflector 10 (for example, a resistor is bonded thereto). Therefore, the temperature of the elastic support member is arbitrarily changed by the heater under the control of the temperature control unit 33 of the control unit 30. In this embodiment, the heater is used as the temperature control element 60 and mounted on the elastic support member. A temperature control element such as a Peltier element can be also used and mounted at any position of the optical deflector, such as a position on the movable plate.

In this embodiment, in order to correct the shifted resonance frequency of the optical deflector 10 based on the drawing data, the temperature control element 60 is controlled to correct a changed temperature of the optical deflector 10 which is caused by the laser light source 20. In other words, when power of light which is emitted from the laser light source 20 within the unit compensation time and

absorbed by the optical deflector 10 is given by  $P_{dr}$ , and the amount of current supplied to the temperature control element 60 is given by  $I$ , a temperature  $T$  of the optical deflector 10 which is maintained within the unit compensation time is expressed by  $T = C \cdot P_{dr} + D \cdot I$  (Expression 3). In Expression 3,  $C$  denotes a power-temperature conversion factor and  $D$  denotes a current-temperature conversion factor. The power-temperature conversion factor and current-temperature conversion factor are measured in advance and stored in the temperature control unit 33. The temperature  $T$  of the optical deflector 10 within the unit compensation time is constantly maintained to a predetermined temperature during an operating period of the image-forming apparatus. Therefore, the resonance frequency of the optical deflector 10 is stabilized regardless of drawing data, so that preferable image formation can be realized. The power  $P_{dr}$  of light with which the optical deflector 10 is irradiated within the drawing time 42 can be grasped in advance by the light source control unit 32. Based on the power, the temperature control unit 33 determines a current to be supplied to the heater using Expression 3 and executes the supply of the determined current.

In each of the above-mentioned embodiments, the unit compensation time is set to a time sufficiently

shorter than the oscillation stabilization time of the optical deflector, i.e., to 1  $\mu$ sec. The unit compensation time may be any time shorter than the oscillation stabilization time of the optical  
5 deflector.

(Fourth Embodiment)

Next, a fourth embodiment of the present invention will be described with reference to the drawing. FIG. 8 is a structural diagram for  
10 explaining a method of controlling an image-forming apparatus according to this embodiment. In this embodiment, the control method for the image forming apparatus (as described in each of the above-mentioned embodiments) according to the present  
15 invention is applied to a laser beam printer (LBP). According to the method for controlling the image-forming apparatus in this embodiment, the resonance frequency of the optical deflector is stabilized. Therefore, a preferable image can be formed on a  
20 photosensitive drum 65 regardless of drawing data.

(Fifth Embodiment)

Next, a fifth embodiment of the present invention will be described with reference to the drawing. FIG. 9 is a structural diagram for  
25 explaining a method of controlling an image-forming apparatus according to this embodiment. In this embodiment, the control method for the image forming

apparatus according to the present invention is applied to a projector. One-dimensional scanning light from the image-forming apparatus 1 is projected and two-dimensionally scanned to the screen 72 by  
5 using a vertical optical deflector 71. Even in the method for controlling the image-forming apparatus according to this embodiment, the resonance frequency of the optical deflector is stabilized. Therefore, a preferable image can be formed on the screen 72  
10 regardless of drawing data.

This application claims priority from Japanese Patent Applications No. 2004-192338 filed June 29,  
15 2004 and No. 2005-135499 filed on May 9, 2005; which is hereby incorporated by reference herein.

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